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NOBLE GAS CHARACTERISTICS IN TEKTITES. R. L. Palma and M. N. Rao, Department of Physics, Sam Houston State University, Huntsville TX 77341, USA.

We have determined the elemental and isotopic composition of all the noble gases in five large samples (~1–3 gm) of tektites from Bedias, Texas [3]. The purpose of this study is to determine the abundance pattern of noble gases in these samples for comparison with those determined in tektites from other strewn fields throughout the world. In Table 1 we show the range of values for the fractionation factor $F(m) = [(^{i}X/^{36}Ar)\text{sample} / (^{i}X/^{36}Ar)_{air}]$ where i is the isotope of element X. One prominent feature that showed up in all of these tektites is the enormous enrichment of Ne, by up to a factor of few thousand, relative to the air. The isotopic composition of Ne in all these tektites is quite similar to that of air, suggesting that Ne in these tektites is of atmospheric origin. The light noble gas results alone do not seem to be sufficient to draw clear distinctions in tektites from the major strewn fields in Australia, Czechoslovakia, and North America.

Our work suggests that the heavy noble gases Kr and Xe may provide a way of distinguishing bediasites from other tektite groups. The F(m) values for Xe fall between ~100 and 300 in bediasites, whereas the F(m) values determined in tektites from the other strewn fields lie between 2 and 10, except for one australite in which a value of 28 was determined [1]. The F(m) values for Kr in bediasites (11–44) are also higher than those determined from other strewn fields (0.02–5) by approximately the same factor as in the case of Xe. Thus it appears that the heavy noble gas results in bediasites are clearly different than those values determined in tektites from other strewn fields.

TABLE 1. Range of F(m) factors (range) in tektite groups from different strewn fields.

Tektite Group	^{4}He	^{20}Ne	^{36}Ar	^{84}Kr	^{132}Xe
Bediasites [1,3]	7100–13400	410–4300	=1.00	11–40	93–340
Australites [2,3]	170–5400	750–1600	=1.00	1–5	2–28
Moldavites [2,3]	690–1400	2300–2800	=1.00	1–3	11–43*
Indochinites [2,3]	87–770	220–2800	=1.00	0.6–1.1	5–12
Thailandites [2,4]	57–3500	2500–11000	=1.00	0.02–0.6	0.8
Phillipinites [3]	630	2100	=1.00	5	6

* Upper limit.

Matsuda et al. [1] and Matsubara and Matsuda [2] attributed the high F(m) values for Ne observed in tektites to the diffusion of atmospheric Ne into these glasses after solidification. We will examine whether the heavy noble gas enrichments in bediasites can also be understood from the viewpoint of diffusion of atmospheric gases into these tektite glasses. In addition, the enrichment of heavy noble gases in bediasites seem to provide clues about the noble gas composition of source rocks or sediments from which these glassy objects are generated by impact. To further investigate this possibility, we will also present data obtained from Georgia and Ivory Coast tektites, both of which have never been analyzed for heavy noble gases. Since the Georgia tektites are believed to originate from the same impact as the bediasites, their heavy noble gas compositions should show the same large F(m) values.

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COMPLEMENTARY REE PATTERNS IN SPATIALLY ASSOCIATED Ca,Al-RICH INCLUSIONS FROM THE CV3 CHONDRITE EFREMOVKA. H. Palme[1], E. Zinner[2], B. Spettel[1], and A. El Goresy[3], [1]Max-Planck-Institut für Chemie, 55020 Mainz, Germany, [2]McDonnell Center for the Space Sciences and Physics Department, Washington University, St. Louis MO 63130, USA, [3]Max-Planck-Institut für Kernphysik, 6900 Heidelberg, Germany.

Efremovka, together with Vigarano and Leoville, is a member of the reduced subgroup of CV3 chondrites. Their chondrules, Ca,Al-rich inclusions (CAIs), and single olivine grains have suffered less nebular alteration than those in meteorites of the oxidized subgroup (Allende, Arch, Bali, Grosnaja). The contents of volatiles (Na, K, Ga, Zn, etc.) and of FeO in chondrules and refractory inclusions in oxidized subgroup meteorites are much higher than in reduced subgroup meteorites [1]. The latter are therefore better candidates for studying the record of high-temperature nebular processes. Inclusions in reduced subgroup meteorites are, however, studied much less than Allende CAIs.

Ten CAIs from Efremovka were analyzed by INAA. Sections were prepared and analyzed by EMP (Heidelberg) and IMP (St. Louis).

Most inclusions are enriched in W, and to a lesser degree, in Mo compared to other refractory metals (Ir, Os, etc.), in agreement with an earlier analysis of a fine-grained Efremovka inclusion [2]. It is possible that superrefractory condensation occurred at slightly oxidizing conditions, resulting in incomplete condensation of W and Mo [3]. The uncondensed fractions of both elements were then incorporated in later condensing phases. This event must have occurred at high temperatures before condensation of Na and other volatiles. The opposite, occasional loss of W and Mo and high contents of volatiles is characteristic of Allende and other CV3s of the oxidized subgroup. The W and Mo depletions and/or enrichments are apparently decoupled from volatile-element enrichment.

Refractory lithophile element patterns in most Efremovka inclusions show some affinity with group II patterns as, for example, reflected in higher-than-chondritic La/Lu ratios. Inclusion EF101 described earlier [4] consists of two adjacent refractory inclusions embedded in the Efremovka matrix. One of the inclusions, EF101.1, is a compact type A inclusion. All constituents (80% melilite, perovskite, diopside, and anorthite) display superrefractory patterns of refractory lithophile elements (RLE) with superimposed crystal-controlled redistribution, in particular of Sc, Zr, and Y, suggesting at least partial melting of the inclusion [4]. EF101.1 is the first CAI with a superrefractory pattern from a CV chondrite. The large abundance of inclusions lacking the most refractory elements (i.e., with group II patterns) in Allende and other CV3s has long been a puzzle. Now there is at least one inclusion in these meteorites with the complementary pattern.

The adjacent inclusion EF101.2 is a fine-grained object consisting of major Cr-bearing spinel and Ti-fassaite. It is chemically uniform and has a distinct group II pattern as analyzed by the IMP. The average CI-normalized La/Lu ratio in EF101.2 is 147, compared to 0.27 in perovskite, the main REE carrier in superrefractory inclusion EF101.1. Fassite in EF101.1 has 0.07 and even melilite has a lower-than-chondritic La/Lu ratio (0.5), although this phase has a strong preference for light REE. The bulk sample (EF101. 1 + EF101.2), however, is nearly chondritic in the La/Lu ratio (1.11) as analyzed by INAA. Apparently, the two adjacent refractory inclusions have complementary refractory lithophile element (RLE) patterns. The approximately chondritic ratios of RLE in EF101. 1 + EF101.2 indicate that these two inclusions have successively sampled a single nebular reservoir, depleting it of superrefractory elements in the first stage followed by condensation of the residual RLE in the second stage.

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PROBLEMS WITH Re-Os ISOCHRON DETERMINATIONS. D. A. Papanastassiou, H. H. Ngo, and G. J. Wasserburg, The Lunatic Asylum, California Institute of Technology, Pasadena CA 91125, USA.

We have developed closed-system techniques for the equilibration of Os isotopes and for the calibration of Re and Os tracers using high-purity metals [1]. The results show reproducibility of ±0.5% for calibrations for Os using different chunks of the same high-purity Os metal produced by vacuum

arc melting. However, samples of two different high-purity Os metals yield a difference of 1.7%, indicating the presence of nonstoichiometry in the Os metal samples and the need for their further purification and characterization. The reproducibility for Re is satisfactory at ±0.2%. Based on the reproducibility of analyses using six different chunks of the same Os metal sample and of Re metals we expect the precision in Re/Os to be ±0.5%, although the accuracy is as yet not better than 1.7%. We have applied the same closed-system dissolution techniques to samples of IIA iron meteorites and we expect the analytical precision for irons to be also 0.5%. We find that analyses of four different chunks of Tocopilla show substantial dispersion in both the Re and Os concentrations of up to 12%, indicating sample heterogeneities in Re and Os. The variations in Re and Os concentrations are correlated so that the Re/Os ratios show a reduced but still substantial dispersion of 2.8%, which is much larger than the analytical precision. Repeat analyses of three chunks of Negrillos also show a substantial range in Re/Os of 1.4%. For each meteorite, the $^{187}Os/^{188}Os$ ratios of these samples are uniform, within 2 εu. Therefore, on a Re-Os evolution diagram the analyses of Negrillos and of Tocopilla are displaced along horizontal lines and are not consistent with a well-defined isochron. The dispersion in Re/Os for different small chunks of the same meteorite accompanied with uniform $^{187}Os/^{188}Os$ can reflect relatively recent Re-Os mobilization or unresolved artifacts in the analytical procedures. By comparison, (1) a well-defined isochron has been reported for IIA irons [2], which appears at odds with our results; (2) low-Ni, IIB irons [3] do not fall on the IIA isochron defined in [2]; (3) Re and Os concentrations in different chunks of IIIA irons are not uniform and the Re-Os data do not fall on a well-defined isochron [3]; (4) IVA irons show deviations of ±1% in $^{187}Os/^{188}Os$ from the IIA iron data and are not consistent with an isochron [4]; and (5) Re-Os analyses on a few irons from different classes are reported to fall on an isochron within 1% [5]. We conclude that is unclear whether whole-rock samples of irons of individual classes of iron meteorites (including the IIA class) define isochrons.

In light of these observations, one must consider the evidence for phases in which Re and Os may become redistributed. We note that the IIA irons are composed of large or single kamacite crystals and do not contain taenite. This may hinder redistribution of Re and Os and may allow the IIA irons to define isochrons in preference to other magmatic iron classes. However, the IIA irons also include ubiquitous rhabdites, up to 20 mm in length, and troilite-daubreelite nodules [6,7]. It has been observed that rhabdites are extremely rich in Pt-group elements. In addition to these considerations, Negrillos and Tocopilla were found in nitrate deposits and show evidence of corrosion [7]. Therefore, it is possible that different samples of these meteorites have been differentially weathered, although our samples appeared fresh. We conclude that it is important to identify the phases in which Re and the PGEs are located and to address in detail the evidence for Re and Os remobilization.

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ORTHOPYROXENE AS A RECORDER OF LUNAR CRUST EVOLUTION: AN ION MICROPROBE INVESTIGATION OF Mg-SUITE NORITES.

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The lunar Mg suite, which includes dunites, troctolites, and norites, could make up 20–30% of the Moon's crust down to a depth of 60 km. The remainder is largely anorthositic. This report focuses on norites (~orthopyroxene plus plagioclase) because we have found that the chemical characteristics of orthopyroxene are effective recorders of their parental melt compositions. Many of the samples representing the Mg suite are small and unrepresentative. In addition, they are cumulates and thus are difficult to study by whole-rock techniques. Therefore, we decided to study these rocks by SIMS techniques to analyze a suite of trace elements in orthopyroxene. The 12 norite samples we report on in this paper were selected from a recent compilation by Warren [1] who attempted to select the best candidate samples from the standpoint of their pristine character, i.e., not formed by or contaminated by impact processes. Our present database includes >300 superior EMP analyses and >50 SIMS analyses for 8 REE, Zr, Y, and Sr.

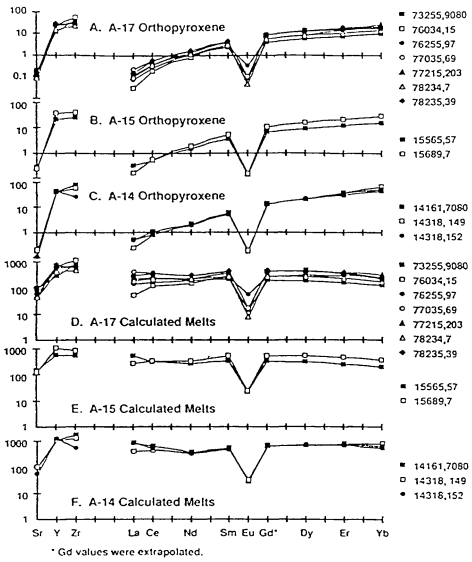

Fig. 1. Mg-suite orthopyroxene and calculated melt REE patterns.

The Mg#s for the parental melts calculated from Mg#s in orthopyroxene show that most melts have Mg#s in the range of 0.36–0.60. This compares with a range of Mg#s for lunar volcanic picritic glass beads of 0.4–0.68 [2]. Therefore, although the cumulate whole-rock compositions of the Mg suite

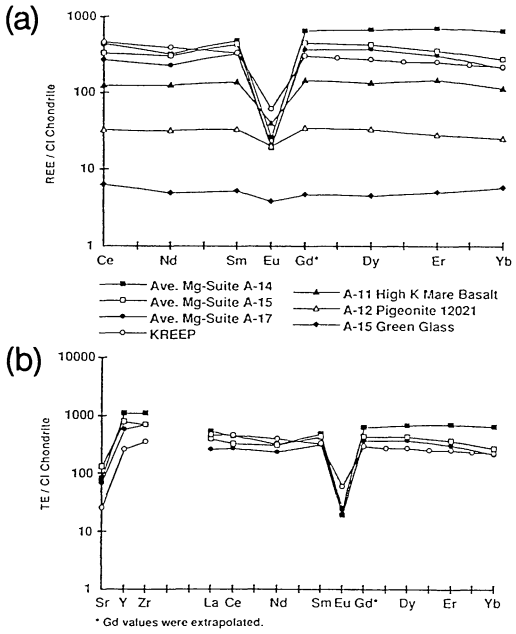

Fig. 2. (a) Selected lunar REE patterns. (b) Mg-suite and KREEP patterns.